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Authors:

Vanderbloemen, Laura1

Dorling, Danny2

Minton, Jonathan3

Affiliations:

1. Population Health Research Institute, St. George’s, University of London [Corresponding Author]
2. School of Geography and the Environment, University of Oxford
3. School of Social and Political Sciences, College of Social Sciences, University of Glasgow

Email addresses:

1. [l.vanderbloemen@sgul.ac.uk](mailto:l.vanderbloemen@sgul.ac.uk?subject=)
2. [danny.dorling@ouce.ox.ac.uk](mailto:danny.dorling@ouce.ox.ac.uk)
3. [jonathan.minton@glasgow.ac.uk](mailto:jonathan.minton@glasgow.ac.uk)

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Abstract and additional information

ABSTRACT

INTRODUCTION: Previous research showed that early adult males in the USA have, since the 1950s, died at a faster rate than females of the same age. In this paper we quantify this difference, and explore possible explanations for the differences at different ages and in different years.

METHODS: Using data from the Human Mortality Database (HMD), the number of additional male deaths per 10,000 female deaths was calculated for each year from 1950 to 2000, and for each age of from 0 to 60 years. These data were arranged as Lexis surface and visualised using shaded contour plots. The same values were calculated over the same year and age range for a number of other countries for comparison.

RESULTS: Males currently experience more excess mortality than they did in the past. Coming of age (between the ages of 15 and 25 years of age) is especially perilous for men relative to women now compared to the past in the USA; these visualisations aid in identifying these changes.

CONCLUSIONS: Sex differences in life expectancy are not static. While women may have a natural edge when it comes to life expectancy, this has changed since the 1930s in the USA when the male-female life expectancy gap was narrower. In the same way that young adulthood for women has been made safer through safer antenatal and childbirth practices, it may be time to think about what changes in public policy could make the social environment safer for men.

Already Known and What this Study Adds

WHAT IS ALREADY KNOWN: In richer countries males have shorter life expectancies than females. Males also have a greater tendency towards risk-seeking behaviour than females, especially in early adulthood. In the USA, the rate of male excess mortality in early adulthood, compared with females, grew in the decades following the Second World War.

WHAT THIS STUDY ADDS: The rates of excess male mortality in early adulthood in the USA begin from the start of adulthood, and have consistently been equivalent to greater than 10 additional male deaths per 10,000 female deaths at all adult ages from 1950 onwards. Earlier biological explanation appears to explain differences from middle age, whereas other factors are more likely in explaining the mortality excess for young adult males. These other factors are likely to be cultural as excess mortality rates have shown greater variation between years, and between countries, than excess mortality at older ages. Because of this, there is scope to address mortality excesses in early adulthood through public health interventions. The implication of this is that excess male mortality may not be inevitable, and that it was not evident in the USA before 1960, except during the end of both World Wars.

Main Manuscript

Introduction

It is widely accepted that women, on average, live longer than men. At various stages over the life-course, women now have the edge (1-8). Male infant mortality rates are thought to have always been higher than female infant mortality rates (4), but until childbirth became safer more women than men usually died in their twenties and perhaps earlier (9).

Today coming of age, reaching adulthood and leaving the protection (or confines) of parents or carers, confers more of an additional mortality risk for males than for females (10, 11). Males now 'age' both sooner and faster than females. Until recently in all of the world women were at a greater risk of death during child-rearing ages than men (9). Now there are only a handful of countries where women die, on average, earlier than men, but maternal mortality remains a major, if declining, killer worldwide (12).

If trends over the last century are ignored it is easy to think of current sex differences in mortality as simply a product of innate biological differences. This paper aims to challenge that perspective, by showing that age-specific mortality differences between males and females have varied across time, and between countries. Although it is true that everywhere males tend to have higher mortality risks than females at infancy, at early adulthood, and in older years, there have been substantial variations in the magnitude of these differences over time and between nations.

Other recent work has referred to these differences and some attempts have been made to explain them.

Researchers from the Wittgenstein Centre for Demography and Global Human Capital and the Vienna Institute of Demography reported in 2013 in the journal Gerontology that the excess male mortality seems to result from high mortality among subpopulations, more common among men, who experience higher mortality than women and thereby bring down overall life expectancy for all men compared to women. They conclude that these differences are not natural differences but that they result from socioeconomic conditions that could ameliorated (13).

In other animals, there is evidence that males live shorter lives than females though we found no studies that claimed to be able to say definitively whether this was a natural difference or a risk-based difference, or a difference due to other causes. In other animals, the idea that the difference varies has also been explored. For example, it has been observed in populations of birds that sex-biased adult mortality predicts adult sex ratio—which affects various social processes, including male aggression, courtship behaviour and whether males or females look after the young (14).

In humans, the gap in life expectancy between men and women seems to be closing. As life expectancy rises overall, and at the same time women make fewer gains relative to men, it may be that this is because women's risk profiles now are more similar to men’s..  However, this convergence is only apparent after 1980. Men took up smoking much earlier than women (15) and so it may well be a temporary effect of women being more free to smoke in the 1960s and 1970s. Now that smoking rates for both men and women have fallen the convergence may not continue.

These trends have been reflected somewhat in public policy in Europe. In 2012 the European Union ruled it unethical and illegal to require men to pay higher rates than women for life insurance, on the basis that this amounts to unfair sex discrimination against men (16), in spite of differences in mortality risk resulting in higher mortality rates among men at most points across the life course.

The changing nature of inequality in life expectancy between men and women is rarely discussed among health inequalities researchers, presumably because it has not been considered to be an inequality resulting from unfair practices or processes. We wanted to find out whether shaded contour maps, a recently rediscovered method for visualising Lexis surfaces, can us illuminate the issue: is there evidence that this is a natural difference, or is there evidence that this is a risk-based difference, or something else?

We hypothesised that this sex difference is a natural / biological difference and sought to test our hypothesis by observing trends over time: have the differences increased, decreased, or remained static over time? In this paper we ‘fly a series of kites.’ None of these can yet easily be tested statistically without making heroic assumptions about “all else being equal”. Instead of doing that we try to suggest what the most fruitful future lines of inquiry might be given what we can see today and using new methods of seeing the data.

Methods

To see how sex mortality inequalities have varied over time, we used population count and death count data from the Human Mortality Database (HMD). The HMD contains these data for 37 separate countries, separately for males and females. HMD data are available at a 1 year by 1 year resolution, i.e. population count data and death count data are available for each year of age from newborns up to the age of 110 years, and for largely continuous ranges of years. Within the HMD, Sweden has the longest duration of records, with records dating back to 1751. France, Denmark, Iceland, Belgium, Norway and England & Wales then have the next oldest available records, stretching back to the first half of the nineteenth century; and the Netherlands, Scotland, Italy, Switzerland, Finland and Scotland have records that date to the second half of the nineteenth century. These datasets allow changes in sex mortality differences to be tracked for more than six generations, and provide some longer term historical context to more recent changes. The focus within this paper will, however, be on changes that have occurred within the previous fifty years, around two generations, as records from more countries are available over this period (17).

To see how sex mortality inequalities have changed over time, the ratios of male to female crude mortality rates were calculated for each country, age and year combination, i.e.

[ADD equation back]

Where the superscripts, m or f, indicate male or female, D indicates death count, P indicates population count, and the subscripts indicate a particular combination of country, age, and year respectively.

For each country, the mortality rate ratios were arranged into a tabular configuration known as a Lexis surface, with each row representing a different age and each column representing year. [REFERENCES] The Lexis surfaces were visualised as shaded contour maps as described in Minton, Vanderbloemen and Dorling (2013), Minton (2013), and Minton (2014). Contour maps borrow conceptually from orienteering, showing how the height of a surface varies over space. Each contour is individually labelled with its particular value, and traces out a path along the surface where the height does not vary; the presence of many contour lines close together indicates a section of the surface where height varies steeply, and contour lines further apart indicate a more gradual variation over the surface.

Because the Lexis surface is of ratios, such the value 5/4 should be thought of as equal in magnitude but opposite in effect to 4/5, shades are coloured red if the ratios are below 1, indicating a higher female than male mortality rate, and coloured blue if the ratios are above 1, indicating higher rates of male than female mortality. The darkness of the shade is determined by the magnitude of the logarithm of the ratios, so that 4/5 will be as dark but red as 5/4 is dark but blue. The addition of shade to the contours makes it easier to distinguish between high and low sections of the surface at a glance, although perceptual distortions due to people interpreting shades in relative rather than absolute terms mean that it should be interpreted alongside the labelled contours. Before being re-discovered by Minton and colleagues (2013, 2013b, 2014) they were used extensively by Vaupel and colleagues in the late 1980s and early 1990s (Vaupel refs). The origins of using either shading or contours to visualise demographic data are much older. (Kermack etc)

All calculations were performed using the statistical programming language R. (Version 3.1.0). The lattice package (REF Sanyar) was used to produce the contour plots.

**Results**

Using mortality data from the United States across a period of 60 years, we observe evidence that sex differences in life expectancy have not remained static over time. One obvious feature in the diagram below is the “smoking cloud” of very high excess deaths of older men centered around the year 1970. Several decades earlier most (then younger) men smoked and far fewer women did. This “cloud: is well known. The “cliff” in the reduction of mortality inequality by sex at younger ages in the years around 1998 has not been commented on before, or necessarily observed as clearly as we can see it in these diagrams

[Figure 1 about here]

The difference began to increase around 1943 in the United States and intensified for the 15-25 year old age band across the 20th century, most notably around 1975 and 1990.

Another increase in excess male mortality that appears may be a Vietnam war ‘plume,’ i.e the triangle of excess male mortality for men between 1963 and 1998. This could have been due to excess deaths among men because of the Vietnam war, and persisting effects to the health and mental health of men affected by the war.

This excess in male mortality could also have been affected by the incidence of AIDS deaths, far higher for men than women and higher for men ages 30-39 than for other age groups. AIDS emerged as a major cause of death in the population around 1985 and the incidence of AIDS deaths peaked between 1993-1995 before decreasing rapidly (18, d) when therapy became available around 1995 (d).

Since the age band affected in the plume is most apparent for 30 to 45 year olds, there is support for both of these hypotheses, and similarly to previous findings (10,11) perhaps a particularly difficult time in history for men is characterised by not just one major threat to health, but by multiple threats. Between 1963 and 1998, men in the USA faced both the Vietnam War and the Gulf War, the emergence of HIV/AIDS and multiple economic recessions which damaged their traditional role as “breadwinner.” (early 1970s, 1980s and early 1990s recessions).

Beginning around the end of the 1940s, a mortality difference for boys and young men (15-25 years old) appears, intensifies and persists across the period of available data (2010). A possibility is that this increased difference in the USA among 15-25 year olds is due to road traffic accidents, as car ownership became widespread and historically men were driving far more than women. However, the male/female ratio of road traffic deaths in the 15-24 year old age group from motor vehicle accidents decreased steadily from 4.5 in 1950 to 2.5 in 2007 (18). Therefore this does not explain the increasing excess male mortality among 15-24 year olds over this period.

Excess mortality for men was trimmed dramatically around 1995, perhaps indicating better times for men, or worse times for women, or both simultaneously.

[Figure 2 about here]

The ‘Bathtub curves’ shown in Figure 2 illustrate how two vertical slices from the contour maps can be displayed to show the ratio of male to female mortality by age. These can be taken at any of the years from the period of available data (1933 to 2010). For illustration, Figure 2 displays two years: 1933 and 2010. From these two cross sections, it is clear that the male / female mortality ratio is different in 1933 compared to 2010. At most age groups the ratio is fairly stable, but for younger men and women, from 15 to 25 years of age, there is a large ‘hump’ of excess male mortality compared to female mortality visible in 2010. This ‘hump’ is not apparent in the curve for 1933.

[Figure 3 about here]

The excess contour plots in Figure 3 show how the USA compares to other rich developed nations including Canada, Great Britain and Northern Ireland, West Germany, France, Japan and the Netherlands. Looking at a comparable contour plot for Canada, there is support for these ideas. Canadian men would have been similarly affected by AIDS deaths and therapy but not as much by the wars. ?

While excess male mortality in the USA drops off for most men after 1998, the excess male mortality continued for men who were 49 years old in 2005. This is evident by observing the continuation of the darker pink ‘plume' for 49 year olds on the USA contour map. ? These men would have been born in 1956, the year after the US began its involvement in the war (although the main involvement was from 1965 to 1973) (19).

Looking at those men who were 19 (the average of participants in the Vietnam war) in 1965, there is evidence of male excess mortality during the war. Comparing other rich market democracies, the triangular plume is not as evident. If anything, in Great Britain/N. Ireland, there is a kind of a triangular plume but it occurs later than would be explained by AIDS deaths. It appears after 1990 and doesn’t drop off the way the one in the USA does. The Netherlands contrasts with the USA in that the 15-24 year old age group excess male mortality trend is the reverse of that in the USA: over time the ratio seems to lessen for15-25 year olds from the period from 1950 to 2010.   
**Discussion**War, tobacco, traffic, emerging infections/immune disease and economics. During the period from 1933 to 2010 differences in male versus female life expectancy emerged, most notably among younger men ages 15-25, but also among older men who were born around 1918 and 1961.

There are at least 5 possible hypotheses that could explain this excess male mortality:

1. This work and previous work hints at a war effect (in line with Barker effect but more specific to wars = Minton effect :) affecting both those born during a major conflict and those who participate, not only during the conflict but also potentially throughout their lives (Marmar 2014).  
2. The increased difference among 60 year olds which appears around 1950 could have been due to smoking behaviour, more common among men until around 1970.

3. When car ownership became widespread in the USA, men were more likely to drive than women, and also to have fatal traffic accidents. This may have changed by 1995 when young women were as likely to drive as young men, and nearly as likely to have fatal accidents as men, perhaps indicating that seat belt laws and airbag technology have prevented deaths in spite of traffic accidents.

4. Emerging infections during the 1980s such as HIV, and the human response to them in the form of immune disease followed almost always by death may have contributed to the excess male mortality during the 1980s and early 1990s, when AIDS diagnoses were more common among men than women (eg males accounted for 82.4% of all persons with AIDS during the period from 1993 to 1995). The 30-39 year old age group represented the largest proportion of the total number of people diagnosed with AIDS during 1993-1995 (45.2% of the total… 40-49 year olds represented 26.2% of the total and 20-29 year olds represented 16.9% of total diagnoses in that period) (CDC 2001) and protective therapy against the development of the immune disease was not yet widely available. The incidence of deaths among adults with AIDS reached a peak in 1995 and has declined dramatically since then (Osmond 2003).

5. Unemployment may also have played a role across the past 80 years in excess male mortality, affecting young men most. Granados et al reported in 2014 that employees who lose their jobs are at an increased risk of death, and Blakeley et al reported in 2003 that being unemployed was associated with a twofold to threefold increased relative risk of death due to suicide compared to those who were employed (e,f) though neither study claimed to make a causal link, and Lundin et al reported in 2010 that in Sweden the association that they observed between unemployment and mortality may have been confounded by mental health problems, behavioural risk factors and socio-economic position (g).  
To our knowledge this is the first study of historical trends in the sex differences in life expectancy in the USA, but our observations are consistent with other recent studies. Mayhew and Smith reported in 2014 that there is evidence that the life expectancy difference between men and women is lessening in England and Wales, suggesting that the difference is not a natural or biological difference. While it is typical to think of elder nursing homes full of women with few men surviving as long, this may be changing for the next cohort to arrive into the oldest age groups. On the other hand, if the excess mortality among young men that we report continues or increases then this may affect the life expectancy of subsequent cohorts, reversing the trend once again.

There are some limitations to this study. First, we present the visualisations as a way to identify trends in very large datasets, but we do not promote one of the 5 possible hypotheses over another. Further research could look more closely at historical trends and disease-specific incidence in any of the 37 countries with available data in order to draw inferences about specific public policy changes and whether these affected one gender more than another…?

It is possible that male death reporting was more refined earlier on, and that the data for women became more refined during the study period, which would affect these data and the comparability of male and female data, but this would likely have resulted in rounded estimates for age at death for women in the earlier decades, and would not have changed the results that we report here.

Another limitation of this study is that it cannot say whether there is a ‘natural / biological’ longevity advantage for women. If that were true then it could be that the period before the second World War was ‘unnatural’ for women; that is, if women do have a natural longevity edge over men, then perhaps the pre-war period when women in the USA had far fewer rights relative to men and maternal mortality was much higher was the high-risk period for women, negating their natural edge. Once equal rights, birth control and safer maternity practices had been better established, the natural advantage for women re-emerged.

If the differences we see represent real trends, then the peaks in excess male compared to female mortality may represent points or periods in history when men experienced differential stress or threats to well-being, for example economic recessions within the context of male dominated economies.

This paper suggests that sex differences in life expectancy are not just natural differences but that they are also the result of historical societal trends where men and women were differentially protected or stressed compared to each other. ?

If sex differences in mortality are truly a result of human activities and societal structures (or something else) rather than biology, or interacting with biology, then this inequality in health between men and women can be lessened and what activities would lead to longer healthy lives for men as well as for women.

This study attempts to identify what threats to healthy lives need to be identified to prevent this excess mortality in the future.

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